Exploring the use of the Physical Web with Resource-Constrained Communities

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Abstract

Over several years, our team has been involved in participatory design of novel future technologies with people in resource-constrained contexts in India and Kenya. A key motivator is to include these groups, who often have lower literacy, infrequent access to data connections, low exposure to technology, and other constraints, in the process of shaping and appropriating devices and services. This is in contrast to what typically happens in such regions, where technologies from traditional markets (e.g., in USA and Europe) "trickle down" after several years. In this case study, we explore the potential and barriers of one such new platform—the Physical Web—in resource-constrained contexts in Mumbai and Nairobi. The Physical Web is an open source Bluetooth-based beacon system, which aims to provide quick and seamless interaction with physical objects over a web platform. Our goal is to understand how this emerging technology might provide local small enterprise traders in these regions with the facility to quickly and easily create and distribute a simple online presence via a local broadcasting medium. In this case study we discuss the design rationale for the approach in terms of how it might address issues around users' resource constraints, and present initial findings from deployments in the two locations.

Figure 1: A physical web beacon, capable of broadcasting up to around 50 m using Bluetooth Low Energy.

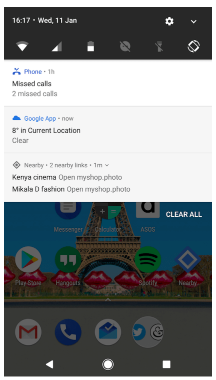

Figure 2: Notifications showing nearby beacons. The Physical Web is intentionally non-intrusive – therefore, simply being in range of a beacon will not present its content. Instead, a notification appears, giving titles and brief descriptions, and prompting the user to explore further if they wish. In this example, there are two beacons in range: 'Kenya cinema' and 'Mikala D fashion'.

Author Keywords
Internet of things; emergent users; HCI for Development; methods; physical web; participatory design.

ACM Classification Keywords
H.5.m [Information interfaces & presentation]: Misc.

Introduction
The Physical Web, like many new mobile and ubiquitous technologies, seeks to enable a range of seamless and enticing experiences. Its goal is to extend the web to physical objects, making them and their services easily discoverable by nearby mobile devices. For instance, at a Physical Web enabled parking meter or vending machine, users can walk up and pay using their mobile phone instead of depositing cash. Similarly, at a bus stop, users can quickly use their own device to see when the next bus is coming without the need for a specific app.

The Physical Web platform[1] enables fast, wireless and app-less access to small chunks of digital information using Bluetooth Low Energy (BLE) beacons. Beacons, as shown in Fig. 1, are discreet and compact, with a short-range signal (typically up to 50 m) and long battery life (upwards of two years) that can broadcast up to three URLs (amongst other data) to their immediate environment. Modern smartphones[2] are able to automatically detect beacons in their nearby area, providing users with a list of the URLs being broadcast in their environment (see Fig. 2).

[1]See Google's project page for the open-source platform: https://google.github.io/physical-web/

[2]The Physical Web is built into Chrome on Android versions 4.3.2 and above, and is available via the Chrome app on iOS. In order to be able to detect Physical Web beacons, phones must have their Bluetooth and location features enabled.

While battery efficient (an essential feature for resource-constrained users), most Physical Web implementations are currently focused on affluent, urban areas where technology exposure and data-connectivity are high. The Physical Web, then, exemplifies a recurrent narrative, whereby the future of cutting-edge, ubiquitous mobile is envisioned and implemented in the centres of high-tech innovation. It tends, then, to be affluent, educated and technology-savvy early-adopters [3] from similarly hyper-developed contexts that first experience and experiment with such new technology, where feedback from such usage is then further used to motivate and shape future iterations.

By the time such iterations reach users in places such as Kenya or India, they are by and large already established. We no longer speak of early users testing out and shaping a new technology, but appropriating a technology that has "trickled down" from often geographically and culturally distant centres of high-tech innovation [4]. It is precisely this narrative that we seek to challenge and disrupt: namely, to take the Physical Web—a cutting-edge technology—to such regions and explore with communities of emergent users [1] the possibilities it presents, and the assumptions and shortcomings it embodies.

This case study is part of a wider body of work [2] that is concerned with conducting extended, future-focused participatory design sessions with emergent users in order to create interactions which are not simply "hand-me-down" ideas, but rather, designs that build on the visions from emergent users themselves. The Physical Web is particularly interesting, because it is still a nascent technology that, while gaining traction with early adopters, has not yet

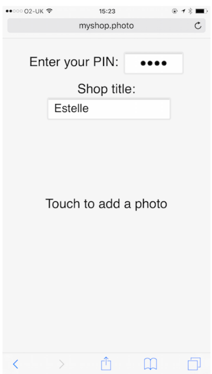

Figure 3: The simple web interface we created to allow stallholders to update the title and image of their shops. For security, sending a new image requires a four-digit PIN known only to the shop owner. To reduce data costs, the image uploaded is reduced in size before upload begins.

been fully standardised. More importantly for emergent users, it is a technology that appears suited to deliver locative media experiences and locally relevant information in ways that accommodate resource constraints. In particular, its low battery drain, and the ability to reduce the need for extensive online searching and browsing, bring associated benefits, ranging from reduced data costs to suitability for people with lower literacy levels and low experience with sophisticated interface interactions.

Context

We have enlisted the help of two emergent communities: one at an itinerant market that visits downtown Nairobi, Kenya; and, another along a busy shopping street in Dharavi – a large slum in the centre of Mumbai, India. The users we recruited were all independent market-store traders who were interested in using technology to help promote and scale their businesses. Traders exhibited a mix of abilities and opportunities in terms of their literacy and access and use of devices, networks and services (such as social media). This diversity of experience, education and access was also seen in the customers that visited their stalls and the people who passed-by.

In discussions with these groups, we identified an opportunity to use the Physical Web to enable the store keepers to quickly create and update an online presence with timely, location sensitive information that customers and passers-by could then interact with when they were nearby the market and stores.

Prototype

We gave each store owner a Physical Web beacon and access to a simple web app. The app allows them

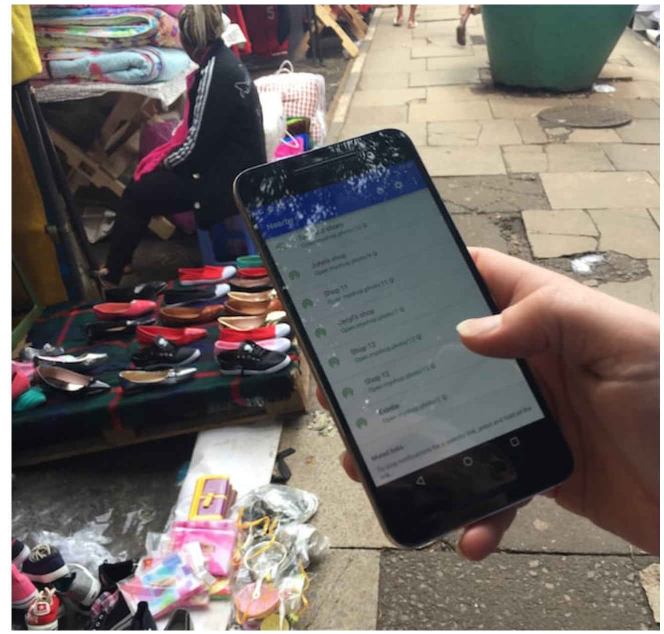

Figure 4: Multiple beacons in range within a shopping district in downtown Nairobi. Selecting any of these will take the user to the simple website of that vendor.

to upload a single image—taken on their own phones—which will automatically appear at the URL on their beacon (see Fig. 3 for the update interface, and Fig. 5 for examples of participant webpages). The image uploaded is entirely of the vendor's choosing – for example, this could be photograph of the stall, or a printed or even hand-written message, or offer precise last-mile directions. Our aim is to see whether this extremely simple yet flexible approach will encourage a wide range of creative solutions for shopkeepers with a range of technological experience and expertise. Stallholders are able to change the image

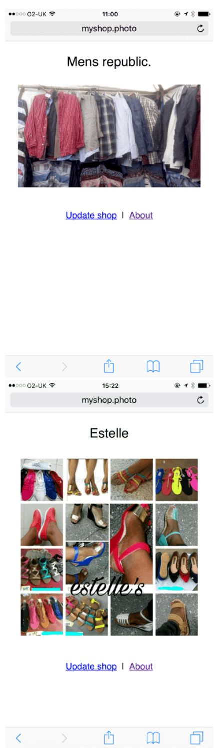

Figure 5: Examples of the web spaces of stallholders from the Nairobi trial. Top: a typical user displaying a single image depicting what they are selling today. Bottom: one of the more technically advanced users we recruited, this lady worked around having only a single image by using a collage of photographs for her page.

and an optional title on their beacon at any time (a unique PIN known only to the shop owner is required for updating). Once updated, passersby with Physical Web enabled devices can then see this image and title when they select that beacon from the notification list. To minimise data transfer costs for both the stallholders and users, these images are reduced in size before being uploaded.

The interactions available to the shopkeeper and customer are illustrated in the scenarios below:

Duma is a local trader who has recently acquired a Physical Web beacon to help him promote his business. He wants to broadcast the details of his shop to the local area via the beacon to give potential customers more information. He takes out his phone and pulls down the notification bar to reveal all the beacons visible to him. Amongst the list is his beacon, which he selects, taking him to his webpage, which currently displays a blank update form (see Fig. 3). After typing in his PIN, Duma is able to change the title of his page and add a single photograph to promote his shop. He takes a photo of his physical business card, which then uploads automatically to his local webpage.

Walking down a busy shopping street, Tia is keen to find a trader who sells swimwear. The market is a bustling area full of people, making it difficult for her to see what wares each stall has on offer. So, she takes out her phone and checks for Physical Web beacons nearby (see Fig. 4). From here she can see a list of nearby vendors, and quickly notices a stall named "Duma's Swimwear". Clicking on the link, she is taken to Duma's webpage, which displays his business card. On this card are photos of his products and his phone number, which Tia calls to get directions and find her way to the stall.

Deployments

We deployed the prototype in the two shopping areas mentioned above, and trained vendors to use it to create their own webspace for broadcast to the local area. The technology is still in place within these two communities, and we are working with local researchers in both Nairobi and Mumbai to check-in with participants and continue analysis. The following sections describe our initial deployment of the probe, and discuss the challenges and lessons learnt so far.

Nairobi, Kenya

We recruited 11 nomadic market stallholders (5M 6F, 22–40) in downtown Nairobi. These stallholders typically stay in one location for several months before moving on to another location within the city. The stalls are tents on the side of the road, arranged in a linear pattern. Products in stalls are predominantly second-hand items of clothing, shoes, textiles and toys, being sold for significantly cheaper prices than the surrounding shops. The rent for each stall is 10,000 KES (~$96) per month. As this cost is relatively high[3], many stalls are occupied by more than one individual sharing the space and the rent.

[3]Kenya's minimum wage is between 12,136 KES (~$116) per month in former municipalities and 15,357 KES (~$148) in major towns such as Nairobi and Mombasa (see: https://goo.gl/syAyyM), with casual workers earning less and at uncertain times.

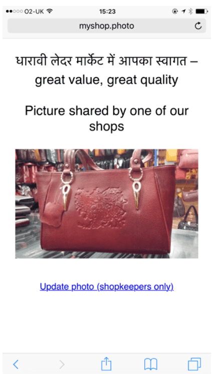

Figure 6: The webpage used in the Mumbai deployment. In this study, the stallholders within the leather district all shared the same webspace. Any of them can update the title and photo, but only one can be shown on the page at any one time.

A prerequisite of taking part in the study was to own, or have access to, an Android smartphone. Other than this, the participants selected for the study had a mix of technical abilities. Some used their phone only to call and send SMS or WhatsApp messages (2 participants), while the remainder had a far larger online presence, using services such as Facebook and Instagram to promote their businesses. Many stallholders had regular customers to whom they sent images of new stock when it arrived either via WhatsApp, Facebook, Instagram or Twitter. None had a bespoke website. All participants had some form of data plan, although the amount purchased was often minimal, requiring daily top-ups, with the majority of users running out by the end of each day.

Mumbai, India

In the centre of India's financial capital, Mumbai, is Dharavi, one of the largest slums in the world. Dharavi covers an area of just over 500 square acres, but houses an estimated one million residents. It is a diverse settlement with an active internal economy, home to many thriving small-scale industries that produce clothing, leather, pottery and plastics made on-site. The majority of the population of Dharavi live and work within the slum, but rely heavily on custom from the surrounding area of Mumbai, making it an ideal setting for our probe.

Our deployment was conducted in the leather district, a bustling area with hundreds of small shops either side of a busy road. As part of the initial trial, we recruited seven shopkeepers (7M, 28–68), all of whom were relatively technology-savvy and interested in promoting their business via digital technology. As with the Nairobi deployment, to take part in the study all store owners had to have the means to update their simple beacon-driven web presence (i.e., owning an Android smartphone).

All but one of the Dharavi stallholders had a data plan, and all had access to WiFi within their place of business (either their own, or shared with another stall). None had a bespoke website (although one did sell some of his wares on Amazon via a friend). Unlike the Nairobi participants, none of the Mumbai cohort used social media to promote their businesses; all the shopkeepers we spoke to in the leather district did, however, have physical business cards with mobile phone numbers as a method of contact.

Procedure

Each initial session began with us explaining the broad nature of the study to participants via the use of mediators who were from the city and spoke the local languages in each location. We gave each stallholder their own beacon which they were free to keep after the study. We then demonstrated how to create and update the webspace with a title and image using a test device. As part of this setup process we gathered general demographic information, and discussed stallholders' use of digital devices and services and the ways they interacted or wanted to interact with their customers. Session times varied significantly from around 20 min to 1.5 hours depending on the engagement and experience of the user.

In the Nairobi study, each vendor had their own webpresence (i.e., each had their own URL which could be updated with their own title and image at any time – see Fig. 5 for examples). In the Mumbai study, however, we altered this to provide a single webpresence for the district (i.e., there is a single URL which any of the stallholders can update – see Fig. 6). Only the most recent image is displayed, but the page also includes a message that promotes the entire area regardless of who is currently featured. This change was driven by two factors. Firstly, during the context exploration phase of the work, participants mentioned that they wanted to highlight the area more widely and collectively, in addition to driving business to individual stallholders. Second, during the Nairobi deployment we noticed that even on high-end Android devices beacon discovery was inconsistent, so we hoped that flooding a wide area with multiple beacons broadcasting the same URL would alleviate this issue.

As well as allowing stallholders to keep the beacons, incentives were provided as a token of appreciation for participating in the study. Each shopkeeper was given 1000 INR in Mumbai (~$15) and 1000 KES in Nairobi (~$10).

Initial findings

Participants across both locations were generally positive towards the study and eager to participate in using a technology before it became mainstream. It was clear from our initial interactions with these stakeholders that many are already seeing value in digital marketing – particularly in Nairobi, where most participants already used social media to inform customers of new stock and offers.

Deploying a new technology such as the Physical Web in emergent user contexts, however, has uncovered several issues. As anticipated, the resource constraints experienced by many users in these communities have proven challenging. For instance:

Devices: Although all participants in the study owned an Android device, some of these were too old to run Android 4.3.2, and therefore unable to detect Physical Web beacons. More common, however, was the ownership of recent, but *replica* phones, sold cheaply by Chinese manufacturers. These were unable to detect beacons, most likely because of poor implementation of the Bluetooth stack. Although this did not stop stallholders from updating their webspace (they could manually enter the site's URL into their browser), it did give some insight into the types of devices in the local area, and a suggestion that the number of users who would be able to discover and interact with stallholders' websites might be lower than hoped for.

Memory: Some participants in our study had so little internal storage left on their devices that they were unable to take a photograph to upload to the site. We believe this is a result of both lower-end devices' small capacities, coupled with the fact that very few users in these contexts have additional devices or cloud storage to back-up their media, resulting in the need to archive photographs on their phones.

Battery: Worries about conserving battery life were persistent amongst participants across both regions (as they do not have easy access to recharging resources during the day). Many people we spoke to turn off all non-essential features of their devices to save power. Clearly, this poses a problem for a study such as this which requires both Bluetooth and location services to be enabled to function. Most of the participants across both sites had Bluetooth turned off at the start of the study, and had to be reassured that Bluetooth Low Energy takes up very little power. We also had to work around the instinct of many to turn off the beacons themselves to conserve power, making clear that the battery life should exceed several years.

Data: Although the majority of participants had access to some form of data plan or WiFi, many were very conservative about its use. For instance, around half of those we spoke to had data-services switched off. We attempted to address this by demonstrating to participants that the system used a minimal amount of data, but also by providing airtime for all participants to make full use of the prototype.

Impact, Discussion and Future Work

We see a real opportunity in this work to open up the Physical Web for a highly concentrated population of resource-constrained users, using a technology which has, so far, been focused largely on a more first-world perspective. This case study has described how we have piloted this work in two such contexts which have generated wider interest[4]. Users in our pilot communities in Nairobi and Mumbai were excited at the prospect and very keen to engage with the technology. We are continuing to recruit business owners in these regions (thanks to our team of local researchers), and are in the process of collecting and analysing logs of system usage. Our local researchers are also in close contact with participants, and are recording feedback and suggestions in order for us to refine and improve the technology.

During this deployment, we have given the beacons away free of charge to participants, and will continue to do so for the remainder of our work in this area. Should the Physical Web gain more traction in these contexts, however, it should be noted that the hardware itself is relatively low-cost (~$5 per beacon, and decreasing), and could therefore be affordable for people in these communities who wish to adopt it.

Other than the resource and context issues we faced during our deployment, discussed above, we also experienced some issues with the beacon technology itself (i.e., the broadcast range is sometimes smaller than expected; some beacons can be temperamental and do not show up on all devices, etc.). Despite these technical problems, however, the initial pilot has raised pointers to how such an infrastructure might work, and the barriers to its adoption, in these contexts. We are focusing now on improving the interaction with the technology based on feedback from participants, and are in the process of acquiring and testing more advanced beacons that have longer battery life and broader signal ranges.

One of the biggest challenges we faced during this initial deployment of the Physical Web in these communities, however, was that it has not yet reached critical mass. As such a new technology, despite having the weight of core Android integration behind it, not many people are aware that their devices are able to access beacons around them. Even in the regions for which this technology was originally designed, many users are simply unaware of its existence – particularly given the un-obtrusive

[4] We have already seen media coverage of the deployment in Mumbai – see, for example: goo.gl/7Bc2Pi, goo.gl/KfnRgA, goo.gl/LPr27L, goo.gl/e1cMSE, goo.gl/5fQTQ8, goo.gl/jGfZ98

nature of its design (i.e., users have to actively look for beacons as opposed to receiving push notifications). While this is an intentional design choice to avoid unwanted content, bringing this technology to the more resource-constrained areas of Dharavi and Nairobi where many users lack the version of Android required, or the extensive use of apps and services, then, exacerbated the significant issue, for users anywhere, that the Physical Web is currently used very infrequently in everyday life.

The focus on the simple webpage creator in our probe, however, meant that business owners could still promote a URL verbally or via business cards. It was clear during the initial interviews with participants that some business owners were more technology-savvy than others. Therefore, this webpage creator was very useful for some, but not particularly useful for others. For example, those who used social media as a method of advertising their business wanted more advanced features to be able to curate a collection of images. One way to help fast-track the more technology literate users, then, would be to allow them to link their beacons with their own web spaces (e.g., Facebook, Twitter, Instagram, etc.).

In ongoing work we are looking at ways of stimulating use and refining the interfaces, as well as collecting and analysing website logs. Even at this early stage of the work, it is worth repeating that despite infrastructural and environmental challenges participants faced during the initial deployment, it is valuable and important to not overlook emergent users, but instead to engage with *everyone* to experiment with and shape future technologies.

Conclusions

Until recently, resource-constrained and emergent users have been overlooked as creators and shapers of new and innovative technology, often getting access to devices and services "second-hand" after the more technology-savvy and affluent users have defined the way they are envisaged and used. This leaves a large proportion of the world to make-do with technology that is essentially designed for a completely different user group. The Physical Web is an example of such a technology that emergent users would not typically get a chance to shape and define themselves. We strongly believe that working with emergent users to help stimulate ideas and improve technology is helpful not only to create their own visions of the future, but also to provide a different perspective on more mainstream mobile services used in the rest of the world.

Acknowledgments

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